SOUTH DAKOTA
SCHOOL OF MINES
& TECHNOLOGY

MATLAB Project

Simple S-I-R* Modeling

And a touch of Systems Modeling!

*Susceptible-Infected-Recovered

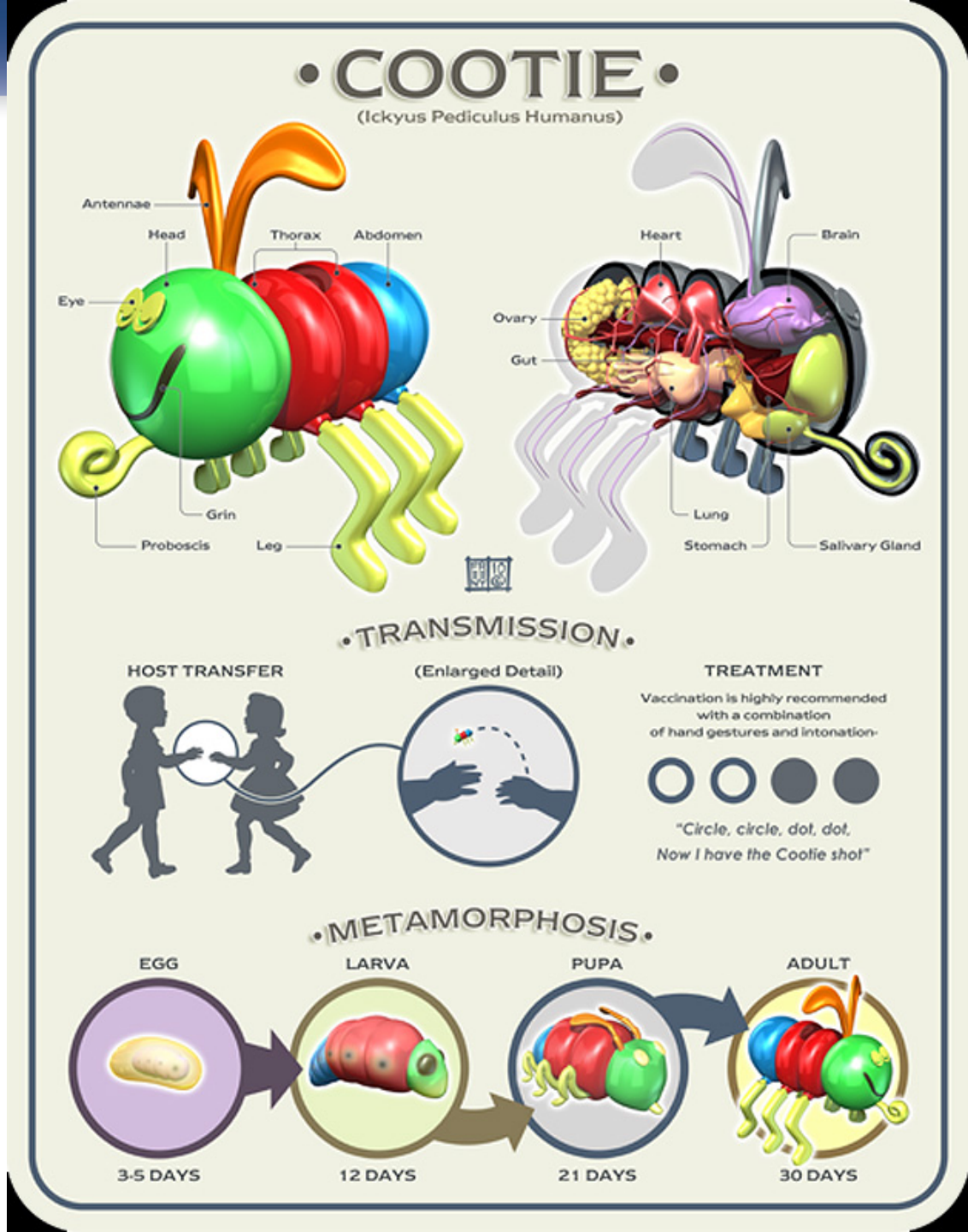
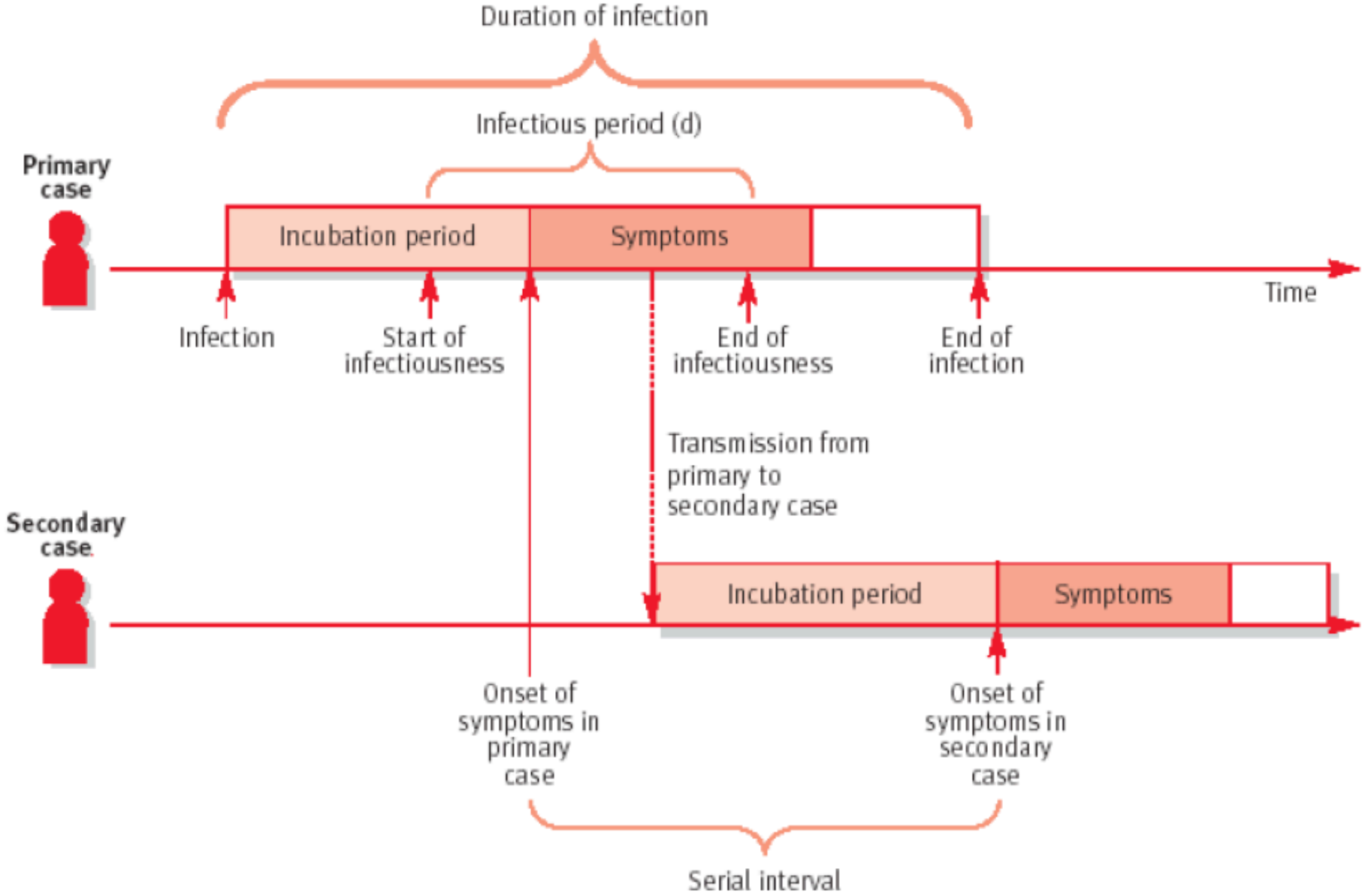


Illustration of incubation period, duration of infection and serial interval



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S-I-R Model

Susceptable
Infected
Recovered

Kermack-McKendrick Model

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Kermack-McKendrick Model

- S=Susceptables
- I=Infected
- R=Recovered
- β=infection efficiency
- γ=recovery rate

$$\frac{dS}{dt} = -\beta SI$$

$$\frac{dI}{dt} = \beta SI - \gamma I$$

$$\frac{dR}{dt} = \gamma I$$

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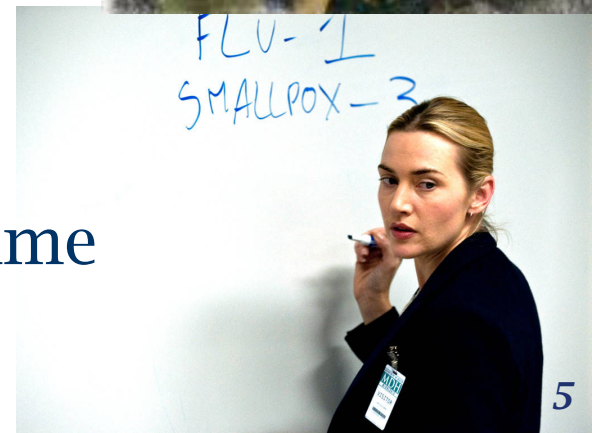
Seen "Contagion"?

Spoiler, Gweneth Paltrow Dies

- Basic Reproductive Rate (Ro)
  - Average # of people infected by a single infected person
  - Ro>1 it will spread
  - Ro<1 it will dissipate
  - Ro~C*P*D
    - C=# contacts / unit time
    - P=probability of transmission
    - D=duration of infection in unit time
- Most are estimated…



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Sample Estimated Ro's

Disease	Transmission	R_0
Measles	Airborne	12–18
Whooping Cough	Airborne droplet	5–6
Diphtheria	Saliva	6–7
Smallpox	Airborne droplet	5–7
Polio	Fecal-oral route	5–7
Rubella	Airborne droplet	5–7
Mumps	Airborne droplet	4–7
HIV	Sexual/Blood contact	2–5
SARS	Airborne droplet	2–5
1918 Influenza	Airborne droplet	2–3
Pink Eye (Conjunctivitis)	Dirty Lab Goggles	~4
Ebola (2014)	Bodily fluids	1.5–2.5

Courtesy of Wikipedia

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Circle Circle Dot Dot

- Herd Immunity…. The more people who are immune, the fewer that will get sick
- Enough herd immunity and a disease will die out

- Threshold Herd Immunity = 1-1/Ro
  - For measles (Ro=12-18) it's ~92% to ~94%
  - Pink Eye if there was a vaccine (Ro=4), 75%

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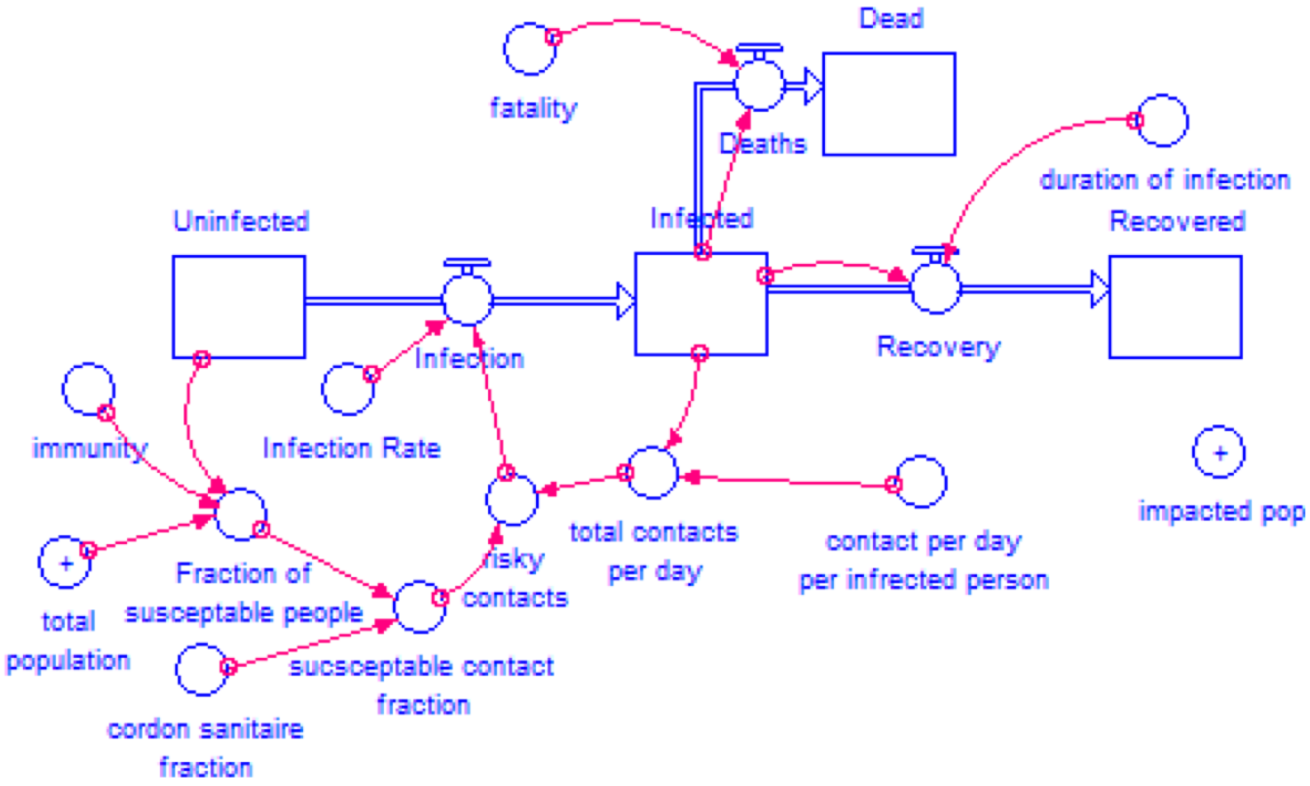
What we'll be constructing

- This is what it looks like with systems modeling software



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The basics of the model

- The disease, and the people it loves to death
  - "Reservoirs" (Literally, People)
    - Susceptible: 9998
    - Infected: 2
    - Recovered: 0
    - Dead
  - Average Infection Period
    - Infection lasts 2 days (1 recovery per patient every two days) or a 50% chance of recovery per day
  - Fatality
    - 10% fatality rate, 1 in 10 dies in a given day
  - Artificial Immunity
    - No immunization before the outbreak. (yet)
    - No sequestration of sick vs healthy during outbreak

The basics of the model

- How the Disease Moves
  - Infectivity Rate: ¼ infections per contact
  - Total Contacts per day: 1 Infected Person Exposes 6 People Per Day

β=infection rate * contact_rate * (1-artificially_immune) / #_Everyone

ɣ=recovery_rate

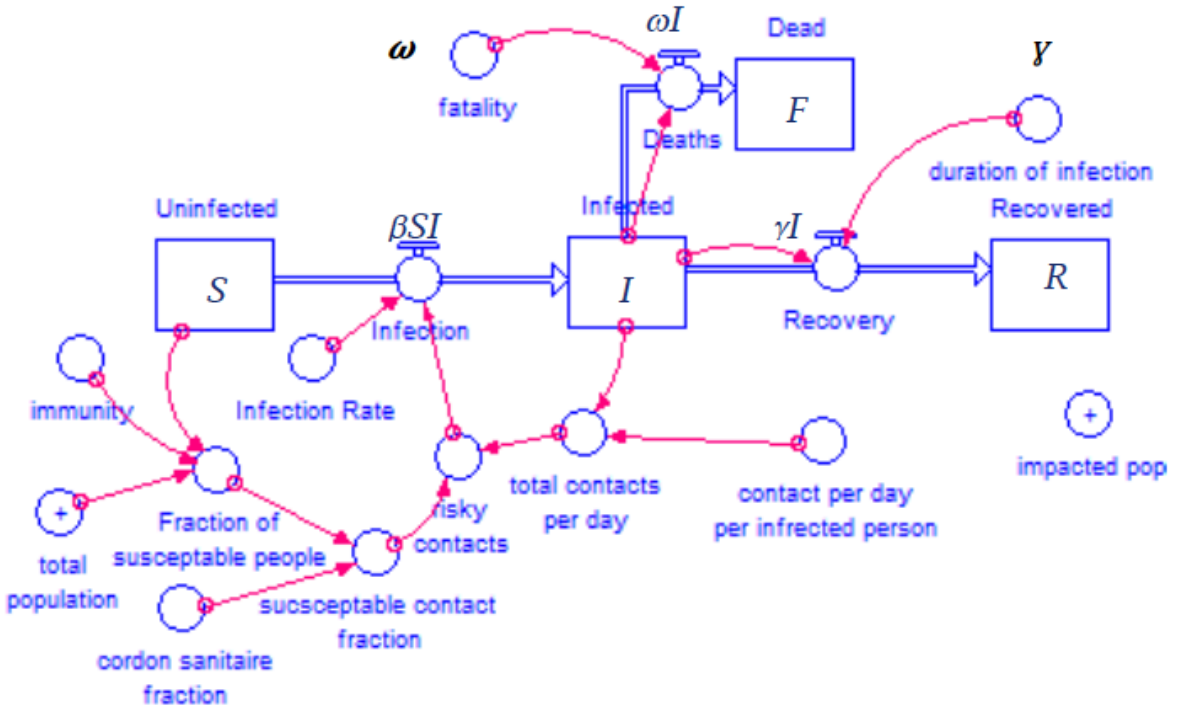
ω=fatality_rate

$$\frac{dS}{dt} = -\beta SI$$

$$\frac{dI}{dt} = \beta SI - \gamma I - \omega I$$

$$\frac{dR}{dt} = \gamma I$$

$$\frac{dF}{dt} = \omega I$$



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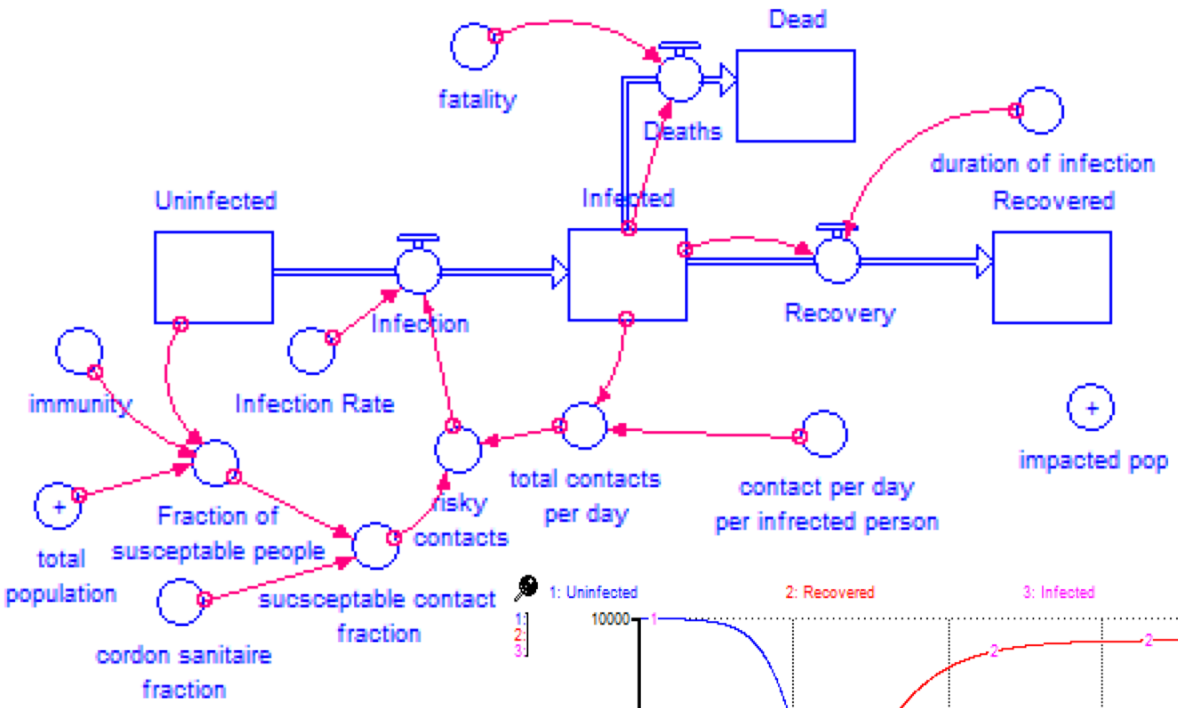
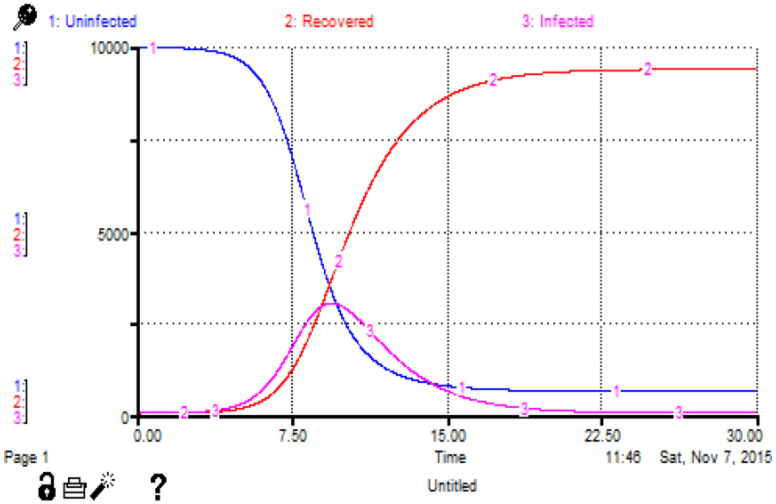
"I got it from Agnes"

- Immunity Rate
  - 0% for now
- Cordon Sanitaire
  - 0% for now
- Now we can funnel in a percentage of healthy people with sick people





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Other things to add.

- Pre-exposure Immunity (Immunization from Mommy)
- Fatality
- Self-limiting contact by sick people
- *Cordon Sanitare* when things get nasty
  - Enough people die
- Multiple levels of illness
  - Stages for
    - Incubation
    - Communicability
    - Symptoms (death goes here)
- Partial Immunity after Infection (reinfection)
- Demonstrate the impact of Herd Immunity

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This outbreak was brought to you by the letters…

- Susceptible (S)
- Infected but not contagious, "Exposed" (E)
- Infected/Infectious (I)
- Recovered (R)
- Maternally Immune (M)

- SIR
- SIS
- SIRS
- SEIR
- SIERS
- MSIS
- MSIER
- MSEIRS
- Etc…

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Now to Play

- How do you eat an elephant?
  - One Bite at a Time!
- We will do this incrementally with short victory laps along the way.
  - Make a loop.
  - Make an if-then-else block
  - Create a “Solver” an area that will crunch the our three equations forward in time

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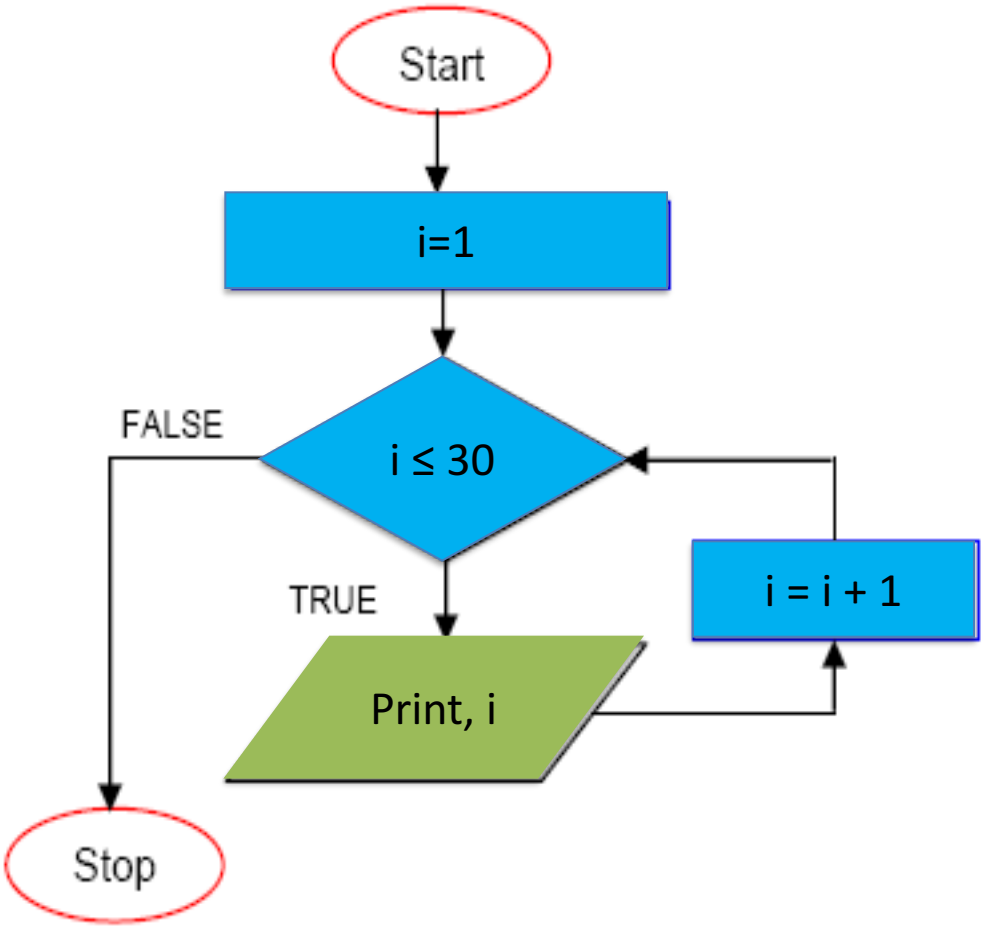
Counting Loops in Matlab

```
Start Program
Loop i from 1 to 30 by 1
        Print i
 End Loop i
End Program
```




```
for i = 1:30
  display(i);
end
```

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Death or Cake? (if then blocks)

```
if (I > 50)
  contact_rate = 6
elseif (I >= 50)
  contact_rate = 3
else
  contact_rate = 2
end
```

```
if (F > 100)
   canned_food = 0.20
   shotguns    = 0.00
end

if (F > 200)
    canned_food= 0.30
    shotguns   = 0.10
end
```

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Victory Lap 1

- Adapt our Euler's Method Code to move things from bin to bin.
  - Infected -> Recovered
  - Infected -> Dead

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Potential Future Victory Laps

- Letting Healthy People Get Sick
  - The rest of the basic SIR model
- Different Scenarios
- Herd Immunity Impacts
  - Get your %(*#@ shots, kids!
- Output to Other Formats (Time permitting)